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ERADICATION OF BIG SAGEBRUSH (ARTEMISIA TRIDENTATA)

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The authors wish to express appreciation to the Grazing Service for their cooperation in setting out demonstrations of sagebrush eradication and to the Forest Service employees of Region 4 who have furnished information relative to sagebrush eradication and reseeding; and to the many private individuals who have volunteered information on equipment designs and procedures in eradication.

ERADICATION OF BIG SAGEBRUSH (ARTEMISIA TRIDENTATA)

By

Joseph F. Pechanec, A. Perry Plummer,
Joseph H. Robertson, A. C. Hull, Jr. [1]

INTRODUCTION

How to eradicate effectively heavy stands of big sagebrush (Artemisia tridentata) is one of the most urgent problems on spring-fall as well as on many summer ranges.

Destruction of some or all of the sagebrush is essential before appreciable increases in grazing capacity and ease of handling livestock can be secured. Without sagebrush removal only slight increases can be obtained on many areas even after good grazing management has been practiced for as long as 15 years. Moreover, it is seldom worthwhile to attempt to increase grazing capacity by range seeding without first thinning the sagebrush because the young grass seedlings face death or severe suppression as a result of competition with sagebrush.

Trials in which sagebrush eradication was followed either by good grazing management, or by reseeding and good grazing management, have clearly shown that eradication pays well in increased forage and ease of handling stock. Range lands with grazing capacities of 10 to 20 acres per animal unit month have been increased 5- to 20-fold in grazing capacity by eradication and reseeding. Other range lands with sufficient grass to make reseeding unnecessary have had their grazing capacity doubled or trebled within 3 years by eradication and good grazing management. In either case eradication of sagebrush has simplified the problem of handling livestock, and wool and lamb losses have been sharply reduced.

Much remains to be done in developing effective equipment and methods of eradicating sagebrush for use in range improvement. Burning, railing, plowing with a wheatland plow, grubbing, ripping, rolling, flooding, mowing, and scraping discussed here as applicable to range land, have been used rather extensively in breaking land for farming. However, relatively little is known of how and when to use most methods in range improvement, their costs and efficiencies, and the best types of equipment to use.

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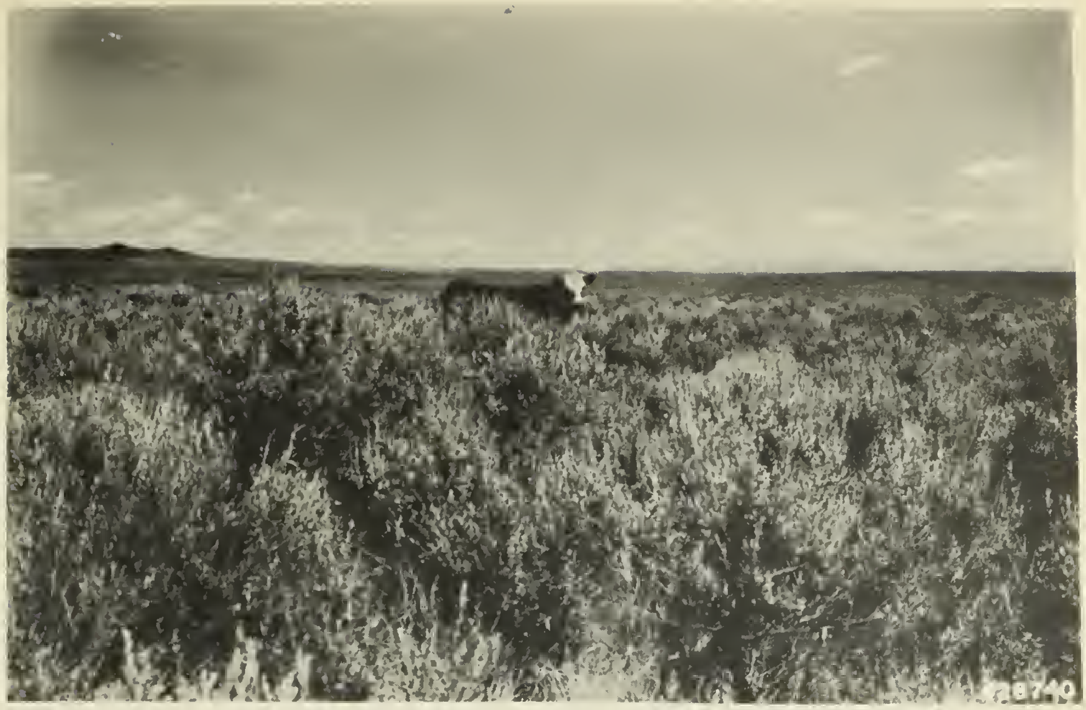

Fig. 1. An effective and economical method of eradicating dense stands of big sagebrush such as this is badly needed. Sheep and cattle cannot satisfactorily graze through such stands, and the sagebrush utilizes much moisture that should be used for the production of grass.

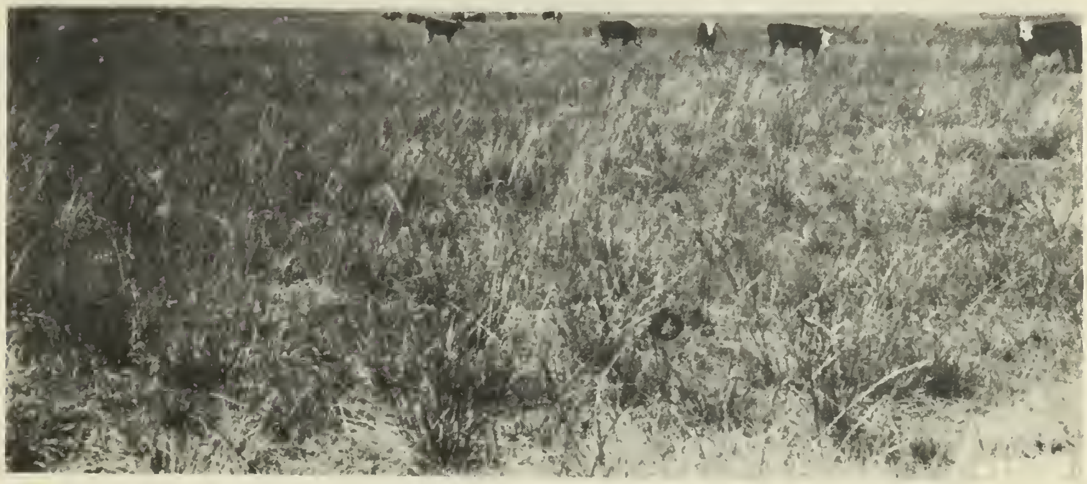

Fig. 2. On this range, burned in 1940, grazing capacity and usability of the range have been increased markedly by sagebrush eradication. Here, because of sufficient understory of grasses, seeding after eradication was unnecessary. This area is less than a mile from that shown in Fig. 1 and before burning was nearly identical in plant cover.

This paper is a summary of certain principles of sagebrush eradication and of the various methods now in use for eradicating sagebrush, discussed as completely as present knowledge permits. It has been prepared primarily as a temporary guide for use by range owners and administrators. It is hoped that it will also act as a base for the assembly of more complete and reliable information.

ERADICATE BIG SAGEBRUSH WHERE RETURNS ARE GREATEST

Where sagebrush eradication will result in a material increase in grazing capacity and a simplification in handling of stock it is generally a worthwhile undertaking. But not all stands of dense sagebrush should or can profitably be eradicated. The protective sagebrush covering should not be taken from the soil unless a perennial grass and weed cover can and will be established through either natural revegetation or range seeding.[2]

Sagebrush should be eradicated only where the danger from erosion is not high. Fairly firm soils and slopes under 30 percent are not likely to be damaged by erosion following sagebrush eradication if a good stand of grass occupies the area or is established through reseeding.

Sagebrush should be eradicated first from the more productive sites because it is here that greatest returns can be expected. Size and density of sagebrush are good criteria of potential productivity. Sites of extremely low potential productivity generally do not warrant the expense of sagebrush eradication unless they fill important places in the seasonal livestock operation.

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[2] Information on where reseeding is likely to succeed, what species to use, and how to plant can be secured from several State and Federal publications. Among those that should be helpful are:

Hull, A. C., and Pearse, C. K. How to Reseed Southern Idaho Range Lands. Research Paper No. 2. Intermountain Forest and Range Expt. Sta. 22 pp., 1943. (Processed)

Plummer, A. Perry, Hurd, Richard M., and Pearse, C. K. How to Reseed Utah Range Lands. Research Paper No. 1. Intermountain Forest and Range Expt. Sta. 22 pp., 1943. (Processed)

Robertson, Joseph H., and Pearse, C. K. How to Reseed Nevada Range Lands. Research Paper No. 3. Intermountain Forest and Range Expt. Sta. 21 pp., 1943. (Processed)

Short, L. R. Reseeding to Increase the Yield of Montana Range Lands. U. S. Dept. Agr. Farmers' Bull. 1924, 26 pp., illus. 1943.

Stewart, George, Walker, R. H., and Price, Raymond. Reseeding Range Lands of the Intermountain Region. U. S. Dept. Agr. Farmers' Bull. 1823, 25 pp., illus. 1939

Eradication should be carried on only where good grazing management is planned and will be provided. Where good grazing practices are not employed afterward, increases in grazing capacity and freedom from sagebrush will be short-lived and expensive in terms of lost range productivity.

ERADICATE DURING SEASON WHEN MOST EFFECTIVE

Season of year during which eradication is carried on is extremely important because it influences the degree of sagebrush kill and the rate of reoccupation.

Methods which uproot, break off, or mash down sagebrush such as railing, ripping, harrowing, and rolling are most effective during the late summer and early fall. The sagebrush is then more brittle than at any other time during the year and the soil firm and bone-dry. At other seasons the sagebrush plants are tough and more pliable. Equipment breakage, especially of rails, is likely to be high in severely cold weather.

Methods which cut or tear up the sagebrush such as plowing, scraping, and grubbing are effective during almost any season that weather and soil conditions permit operation. It is said that grubbing is most easily done in the spring.

It is extremely important not to eradicate by mechanical methods in the fall and winter because the eradication operation may effectively scatter and plant sagebrush seed that ripened during the fall. At higher elevations in the Intermountain region sagebrush seed begins ripening about the middle of September and at lower elevations or in warmer localities it may ripen as late as the last part of November.

SEED AFTER ERADICATION WHERE NECESSARY

On many range lands seeding after eradication, or in the same operation, is needed to bring about revegetation of the range within a reasonable period of time.

WHERE TO SEED

Kind and amount of perennial grasses and weeds now present on the range, and the expected damage to them from eradication, determine whether seeding will be needed.

1. Seed where perennial grasses and weeds now make up less than one-fifth of the plant cover. It is often inadvisable to gamble that perennial grass making up one-tenth to one-seventh of the cover may, within 4 or 5 years, fully revegetate the area. There is a marked urgency to secure a full stand of grass as soon as possible to protect

the soil from erosion; to prevent the early return of an abundance of sagebrush; to prevent invasion by undesirable plants; and to provide a rapid increase in grazing capacity.

Rapid revegetation is needed to protect the soil exposed as a result of burning or other methods which destroy or bury most of the litter. The longer the soil remains exposed, the greater the likelihood of serious erosion especially if the soil is somewhat sandy or the slopes moderate to steep.

Where some mature sagebrush plants are left alive after eradication a good stand of perennial grasses and weeds should be quickly reestablished. The remaining sagebrush plants have an excellent chance to reseed adjoining areas to sagebrush unless competition by grasses prevents survival of sagebrush seedlings.

Where an inadequate understory of perennial grasses and weeds exists there is danger of invasion by undesirable plants following sagebrush eradication. In Nevada a newly introduced poisonous annual weed (_Halogeton glomeratus_) came in on strips that had been cleared and seeded for purposes of range improvement. Successful seeding will not prevent the first-year invasion but it might bring the undesirable annuals under control or repel invasion after the second or third year. Where invasion by pest species is likely, eradication should not be undertaken unless conditions are extremely favorable to quick revegetation by seeding.

A somewhat similar situation may exist near irrigated farm lands of Idaho and Utah. Here sagebrush eradication on lands with an inadequate perennial grass understory may permit invasion by Russianthistle, tumbling mustard, and flixweed, breeding hosts for the beet leafhopper. It is important that such areas be quickly revegetated with perennials to avoid undue exposure of nearby beet, tomato, and bean crops to curlytop disease.

2. _It will be necessary to seed the area if the method used in eradication of the brush destroys a high percentage of the perennial grasses._ Use of the wheatland plow unless plowing is very shallow, the ripper with closely spaced teeth, the grubber, and the grader all kill out a large proportion of the perennial grasses and demand, therefore, that seeding follow eradication.

3. _Seed to improve forage quality._ Where perennial grass or weed remnants provide forage of inferior quality more valuable species should be seeded at the time sagebrush is being eradicated. Eradication methods that destroy a large part of the remnants are needed to permit establishment of reseeded species where the perennial remnants make up more than one-quarter to one-third of the plant cover.

HOW TO SEED

Disk drilling after wheatland-plowing, railing, burning, rolling, or scraping, if the terrain will permit, is ordinarily the most effective planting method. The seed is distributed uniformly and can be placed at the optimum

depth. If ordinary care is taken the drill will not be damaged by going over the burned stubs or piles of uprooted sagebrush and shrubs that remain unbroken.

Drilling as a separate operation is necessary if eradication is by burning or railing, however, the drill may be attached directly behind the plow, roller, or grader. In the latter cases the drill increases slightly the power necessary and may reduce the speed of travel.

Wheatland plows equipped with seeder attachments (tiller combine) eradicate and seed at a single operation. As constructed, some attachments deliver the seed to the bottom of the furrows. This ordinarily is too deep for grass seed. To correct this, troughs or spouts can be constructed to carry the seed back so that it falls in the wake of the disk where it will be covered with soil either from the disk or sloughing in at a later date. In other models this alteration is unnecessary.

Broadcast seeders trailed behind the plow or ripper distribute seed satisfactorily without appreciably increasing the power necessary for propelling the equipment. Soil sloughing or logs dragged behind the broadcaster are relied on to cover the seed. Broadcasters are available commercially or can be improvised by using a drill from which all of the disks have been removed.

Broadcasting seed ahead of the harrow, rail, roller, plow, or grubber from a platform on the tractor gives fair distribution of seed but relies on the implement following to give coverage. This broadcasting may be done by hand, using a hand seeder, or by a mechanical broadcaster similar to that developed for spreading poison grasshopper and cricket bait. However, broadcasting ahead of the plow often results in covering the seed to such a depth that failure or a poor stand results.

Broadcasting seed as a separate operation while walking or riding a horse gives the least satisfactory seed distribution and is often as costly as more efficient methods (table 1). But where better equipment is lacking, or the terrain too rough, it may be the only way left for distributing the seed.

Table 1.- Acres that can be seeded per hour with various types of equipment and cost per acre.

Power and machinery	Acres seeded per hour Average	Cost per acre
Team of horses with 8-foot drill	1.0	$1.00
$1\frac{1}{2}$-ton truck with 8-foot drill	2.0	.80
28-hp. caterpillar, 16-foot drill	4.0	.50
35-hp. caterpillar, 3 12-foot drills	10.0	.33
1 man walking and broadcasting	2.0	.30

More information on where seeding is likely to succeed, what species to use, and how to plant can be secured from the State and Federal publications available on this subject.[3]

GRAZE PROPERLY AFTER ERADICATION

Good grazing management is necessary regardless of the method of eradication. It is one of the most important factors determining whether eradication produces range improvement, and the length of time dense sagebrush will be eliminated as a range problem.

Five points to be observed in grazing ranges after sagebrush eradication are as follows:

1. Protect cleared areas from trailing the first fall. Trailing livestock across the cleared area during the first fall stirs the soil and speeds erosion. The trailing livestock bring in sagebrush seed, primarily in their fleece or hair, and scatter it over the cleared areas. Young sagebrush seedlings that come up early the following spring will be firmly established before the perennial grasses and weeds thicken enough to prevent it. Thus, trailing alone may be responsible for the return of sagebrush.

2. Graze lightly, if at all, during the first year. No grazing should take place the first fall. Little, if any, should take place the following spring. Grazing the first spring often delays increase in size and abundance of the perennial grass remnants and keeps the plant cover so open that sagebrush can successfully return. Furthermore, grazing the open plant cover disturbs the inadequately protected soil and may speed up wind and water erosion.

An appearance of abundant green growth the first spring is misleading. The dense sagebrush formerly screening the herbaceous understory has been broken down or removed and most of the perennial grasses and weeds on the area are now visible at a single glance. Thus, there appears to have been a striking increase in forage production when actually there may have been a decrease.

3. It is particularly hazardous to graze a newly seeded range. Young and weakly rooted grass seeds are easily damaged by grazing before they become firmly established. The danger from grazing the first year is much more serious where few if any perennials survived eradication and seedlings make up most of the forage on the area.

4. Graze lightly the second year and moderately thereafter. Rate of grazing should be based on the abundance of perennial grasses and weeds.

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[3] Ibid. p. 2

5. Use other practices that promote good grazing management. These include good distribution of livestock, proper season of use, open herding, proper location of salt grounds, and rotation grazing management. These and all other practices that further good range use should be employed to help in maintaining the increased grazing capacity and usability of the range resulting from eradication of sagebrush and subsequent revegetation.

CHOOSE A METHOD SUITED TO THE SITE

Because of the widely varied conditions under which dense sagebrush grows no method of eradication is universally the best. Methods which may be best on some sites are not usable and are often too costly on other areas.

The following six points should be considered in choosing a method for any site:

1. A method should be used that kills most of the sagebrush. As a general rule the more complete the kill of sagebrush the better the method. When sagebrush is completely killed it will return very slowly because the seed source has been largely eliminated.

2. Perennial grass and weed remnants should be damaged as little as possible if there are enough left to justify consideration. On many ranges enough desirable grasses remain to revegetate the area after sagebrush is removed. They may only need release from the competition of the sagebrush. Methods which destroy these remnants make necessary reseeding after eradication, thereby increasing costs and decreasing certainty of range improvement. Even though remnants are too scattered to revegetate the area without reseeding they are often worth saving.

3. Where reseeding is necessary a method which combines eradication and planting is desirable. Costs will be reduced thereby. On the other hand, if a separate seeding operation will improve the effectiveness of seeding the added cost may be worthwhile.

4. Wide applicability is desirable. A method equally effective for eradicating young and old sagebrush as well as other undesirable shrub species, and also effective at many seasons of the year on rocky ground or deep soil, and on steep slopes or level ground, is much more useful than one applicable to only localized conditions.

5. Costs need to be as low as possible, consistent with the kill of sagebrush and the increases produced in grazing capacity. Low-value range land usually does not warrant large expenditures. Supervision and labor; transportation of men, equipment, and materials; initial

costs of new equipment; equipment operation, repair, and depreciation[4] are all to be considered in calculating costs.

The cost of sagebrush eradication varies with the method, but not as widely as variations introduced within a single method by varying degrees of experience in eradication work, care in planning the job, size of tract, and current labor and equipment costs.

6. Choose a method utilizing equipment near at hand or one which is adapted to other uses. Unless a large amount of eradication work is anticipated purchase or construction of expensive equipment may not be warranted.

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[4] Many of the data on costs of different methods used in this paper have been compiled from jobs completed in different localities or in different years. Since labor and equipment costs vary so widely from year to year and between localities it has been essential for purposes of comparison to compile these records using the following set of equipment rates and wages:

Wages	Per Hour
Tractor, grader, or motor patrol operator	$0.75
Ordinary laborer	.60

Equipment Charges (Crawler-type tractors)	Oper. & Repair	Depr.	Total per Hour
33 hp. and under	$0.70	$0.40	$1.00
30 hp. to 44 hp.	1.15	.50	1.65
45 hp. to 59 hp.	1.25	.65	1.90
60 hp. to 80 hp.	1.40	.70	2.10
Wheatland plow			.13
" " with seeder attachment			.15
Road ripper			.20
Grain drill			.10

To enable the interested reader to compile costs according to his own system, these cost figures have been supplemented in the following discussions by figures on the average rate of eradication and seeding per hour.

Costs of seed and costs of seeding are not included in the costs of eradication. Some representative costs of seeding by different methods are given in this paper under the section on "How to Seed." But no seed costs are given since these vary so widely according to species, amount of seed, and current seed costs.

METHODS FOR ERADICATING SAGEBRUSH

Most eradication methods are mechanical either employing equipment built for other purposes as the road ripper and wheatland plow; equipment built for eradication of other types of brush as the roller, mower, and brush-cutter; or equipment built specifically for sagebrush eradication as the sagebrush rail, sagebrush grubber, and self-clearing harrow. Two nonmechanical methods, burning and flooding, have been used. No known effort has yet been made at biological eradication.

The six most common methods for eradicating sagebrush are evaluated in table 2 on the basis of present knowledge. These and four other methods are discussed in the catalog of methods that follows the table. At present, burning and use of the wheatland plow and sagebrush rail appear generally the best: burning because of low cost, adaptability to rocky areas, and complete kill of sagebrush; wheatland plowing because it uses an implement available commercially and results in a high sagebrush kill, prepares a good seedbed for range seeding at a moderate cost; and railing because of low cost, fairly high sagebrush kill, and rapid rate of accomplishment.

This doesn't mean that other methods may not be equally desirable. Further study and development may prove them to be.

BURNING SAGEBRUSH

The use of fire to eradicate sagebrush is one of the oldest and most widely adaptable methods, but it is also the most frequently misused. Fire can be extremely useful, but to insure range improvement it must be used skillfully.

Advantages of Planned Burning

1. Burning is widely applicable to young and old sagebrush, both on extremely rocky or deep soils.

2. For fairly sizable tracts the costs are extremely low.

3. Ordinarily very few of the desirable perennial grasses and weeds are killed out. If burning is conducted at the proper time, reduction in vigor of grass remnants the first year is not likely to exceed 30 or 40 percent.

4. Sagebrush eradication is usually complete.

5. Reseeding can be easily carried out afterward.

Limitations of Planned Burning

1. Fire is easily misused, and extremely dangerous if carelessly handled.

Table 2.- Summary of limitations and advantages of six most common methods of sagebrush eradication

	Method of eradication					
	Planned burning	Wheatland-plowing	Railing	Self-clearing harrow	Road ripper	Spiked roller
Kill of large, old sagebrush	100%	80-95%	75-99%	20-80%	60-80%	60-90%
Kill of young, flexible sagebrush	100%	60-90%	30-60%	5-30%	5-15%	10-50%
Kill or loss in vigor of perennials	30-40% loss in vigor first year, low kill	High to almost complete kill	Slight to none	Slight to moderate	Slight to moderate	Slight to none
Kill of other shrubs	Slight on most species that sprout	Can be fairly high except in snowberry	Slight on most species that sprout	Slight on most species that sprout	Slight to moderate	Slight on most species that sprout
Maximum slope on which usable	30%	30%		20%	25%	
Rockiness of soil on which usable	No limit	Limited to little or no rock	Moderate, useless on well-imbedded protruding rock	Fairly rocky soils	Actually no limit, slows operation	Limited to little or no rock
Acres treated per hour		1 to 3	6 to 12 one way	1 to 3	3/4 to 1¼	1 to 3
Cost per acre	\$0.25 - 0.35	\$0.90 - 5.00	\$0.25 - 1.00 for one way	\$0.90 - 5.00	\$2.15 - 3.60	\$1.00 - 2.90
Usefulness also as seeding method	No good	Good to excellent	Moderate to poor	Good	Moderate	Moderate to poor
Miscellaneous	Great care needed in use. Not advisable on soils that will blow badly	Reseeding always necessary afterward			Reseeding may be necessary afterward	

2. Burning is not advisable where slopes are steeper than 30 percent, where soils are unstable, or where important grasses, weeds, and shrubs are not fire-resistant.

3. There are many stands of sagebrush, more or less open and without an understory of perennial or annual grasses, that cannot be successfully burned except under conditions of extreme fire hazard.

4. Debris and litter are largely consumed by the fire, completely exposing the soil, grass clumps, and seedlings to erosion, wind, and cold.

Procedure in Planned Burning

Simple, practical rules and guides on where, when, and how to burn, and the grazing management to be used after burning are presented in U. S. Department of Agriculture Farmers' Bulletin 1948, "Sagebrush Burning--Good and Bad."

Costs of Planned Burning

From $0.25 to $0.35 per acre is the average total cost for sagebrush eradication by planned burning. This cost includes the cost of constructing fire lines (approximately $40 per mile), of actually burning the area, and of obtaining additional range for one year to permit protection of the burned area.

WHEATLAND-PLOWING SAGEBRUSH

Plowing with wheatland plows (disk tillers, or harrow plows) has recently become a common practice for sagebrush eradication on range lands.

Advantages of Wheatland-Plowing

1. Wheatland-plowing is highly effective in any type or density sagebrush. Under the best of conditions and handling, 80 to 95 percent of the sagebrush may be killed. Generally, the bigger the brush and the softer the ground the greater the kill.

2. It prepares a good seedbed. When the plow is equipped with a seeder attachment, eradication and seeding can be carried on as a single operation.

3. Debris left on the ground surface protects the soil and the young grass seedlings.

4. Wheatland-plowing appears to work effectively in any season of the year that weather and soil conditions permit.

5. Other shrubs, except snowberry, can be effectively eradicated.

Limitations of Plowing

1. Wheatland-plowing is limited to land with little or no rock. Where well-anchored boulders are frequently encountered it is necessary to go slow to avoid breaking disks, or springing the plow frame. Slow travel means high costs.

2. Nearly all perennial weeds, bunchgrasses, and desirable shrubs, except those spreading by rootstocks, are killed by plowing at a depth adequate to kill sagebrush. Thus, wheatland-plowing is limited to a range possessing little or no understory of perennial grasses and weeds. Shallow plowing to a depth of less than 2 inches may preserve a considerable portion of the bunchgrasses, but is not effective for eradication of younger, more flexible sagebrush plants.

3. Wheatland-plowing is moderately costly with present types of equipment. Costs are not excessive for highly productive spring-fall and summer range lands, but they are too high for low-value spring-fall ranges.

4. In big, dense brush the wheatland plow clogs occasionally. Changes in design such as use of larger diameter disks may largely eliminate this trouble.

Equipment Needed and Procedure

A 40-hp. crawler-type tractor and an 11- to 14-disk plow (fig. 3) provide a convenient unit for sagebrush eradication under most conditions. Wheel tractors of equivalent power may be substituted for the crawler tractor where the ground is fairly level. Smaller tractors could be used on level or moderately sloping ground, but the increased speed that more power permits usually more than offsets the added operation costs of larger equipment. A ratio of from 3- to 3½-hp. per disk seems to be sufficient, but this varies widely with soil, density of brush, and topography. Plows with 26-inch or larger disks are more desirable than those with smaller disks.

Plowing should be as shallow as possible to save power and still provide an adequate kill of sagebrush. Two to four inches is generally sufficient, but where sagebrush is flexible or mixed with rabbitbrush, plowing to a depth of 4 to 6 inches may be necessary.

Ordinarily it is necessary to plow only once, but where extremely dense and rather young sagebrush occurs on clay soils it is sometimes necessary to plow twice to obtain a desirable kill.

Rate Per Hour and Cost

One well-trained operator with a 40- to 45-hp. tractor and an 11-disk plow can average from 1.5 to 2 acres per hour, with a minimum of 1 acre, and a maximum slightly more than 3 acres. Acreages covered are at a

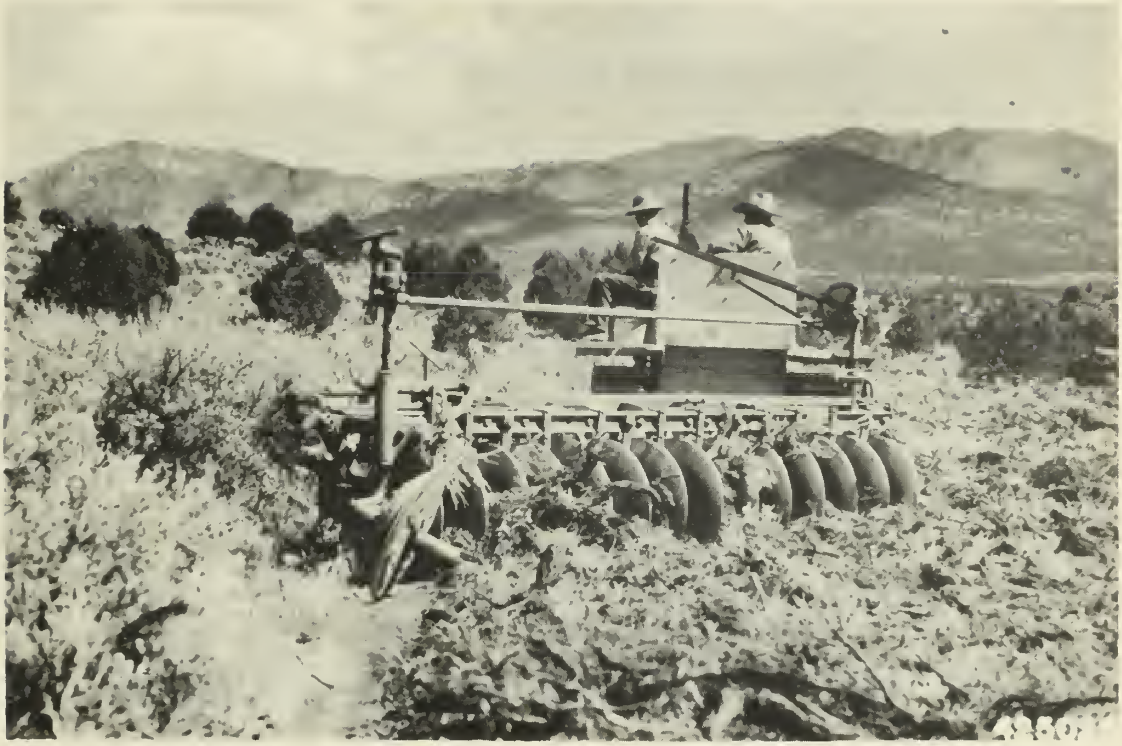

Fig. 3. A wheatland-type plow being used for sagebrush eradication and seeding. The man sitting beside the caterpillar operator is broadcasting seed ahead of the plow. This method of seeding is questionable because the seed is often too deeply planted. If a combined operator is desirable, broadcasting behind the disks generally gives good results.

minimum where the range is broken into tracts of less than 5 acres and the terrain is rough with slopes up to 20 or 30 percent. Maximum acreages can be attained on large tracts of essentially level spring-fall range. Efficiency of operator and type of equipment used also affect rate of plowing.

The average cost per acre of wheatland-plowing is about $1.32, with a maximum calculated cost of $2.64 and a minimum of $0.88. In actual practice costs have run as high as $5.00 per acre because of poor planning, lack of experience in sagebrush eradication work, and lack of experience in the use of a wheatland plow.

RAILING SAGEBRUSH

Uprooting, breaking off, or mashing down dense sagebrush by pulling a heavy rail across it is one of the oldest methods of eradication. This method, extensively used in the early days to clear land for farming, has recently been used for range improvement.

Advantages of Railing Sagebrush

1. Large acreages can be railed per day and costs are low.

2. Most perennial grass and weed remnants are not greatly damaged. Railing may destroy 15 to 35 percent of strongly pedestalled Sandberg bluegrass.

3. Debris left on the ground surface protects mature grass clumps or young seedlings against too close grazing, and the soil against erosion.

Limitations of Sagebrush Railing

1. A satisfactory sagebrush kill is not secured where sagebrush less than 2 feet in height, or younger than 15 to 20 years of age is plentiful in the stand. In even-aged mature stands from 2 to 4 feet or greater in height and on fairly level or rolling ranges as much as 99 percent of the sagebrush may be killed. But only 30 to 60 percent of young, flexible sagebrush is likely to be killed.

2. Large boulders or rock outcrops cause excessive breakage.

3. Other undesirable shrubby species are not killed by railing.

4. Railing is suited to large, unbroken tracts much more than to small 10- to 15-acre patches.

5. Railing generally fails to give adequate coverage to seed broadcast ahead of rail.

Equipment Needed

A crawler-type tractor and a sagebrush rail are all that is required for railing. The size of rail that can be pulled by any tractor depends upon the density of the sagebrush, the topography, and to some extent the rail design. In rather open sagebrush (6 to 8 mature plants per 100 square feet) on a rolling range in the State of Washington a 35-hp. tractor pulled a 40-foot Olson rail at about 2½-miles per hour. In much heavier sagebrush and on steeper slopes near the Cache National Forest in northern Utah a 53-hp. tractor pulled a 32-foot Monte Cristo rail at about 2½ miles per hour. In Nevada where sagebrush was open (8 to 10 plants per 100 square feet) and the range fairly level, a 56-hp. tractor pulled a 32-foot Supp rail with such ease that an estimate was made that it could have pulled twice the width of rail. In southern Idaho where sagebrush was very dense (22 plants per 100 square feet) but the range level, a 35-hp. tractor pulled a 26-foot Olson rail at slightly more than 2 miles per hour.

There are several types of sagebrush rails. No tests are yet available comparing the different types as to efficiency of sagebrush removal and relative amount of power required to pull them. For this reason four detailed drawings and three general sketches of rails are shown.

The Olson rail (fig. 4) has been used effectively and at rather low cost on several thousand acres of range land in Washington. Recently it has been tested in southern Idaho. It is made of 120-pound railroad rail assembled in the form of a shallow "V" and is pulled with the open side of the "V" going forward. At the junction of the two sides is a ball-and-socket joint to permit flexibility. Links of chain will not work satisfactorily in place of the ball-and-socket joint. When sufficiently heavy railroad rails are unavailable, the additional weight and strength may be obtained by building up sections from two or three lighter rails as shown in Sections A-A and B-B of the Monte Cristo rail.

The Supp rail (fig. 5) has recently been used successfully for range improvement in Nevada.

This type rail made of 65- to 90-pound rail, relies on adjustment in slope of the base of the rail rather than weight for its efficiency.

It is easily transported, being built up in sections; clears itself readily of brush; and sections can be added or taken off to make optimum use of power. It has a low original cost because the rail may be built in a ranch blacksmith shop.

But the Supp rail is far from foolproof. Since it relies on adjustment of lever tension, it must be constantly checked to keep it working efficiently. Well-anchored boulders will bend the rails and destroy its efficiency.

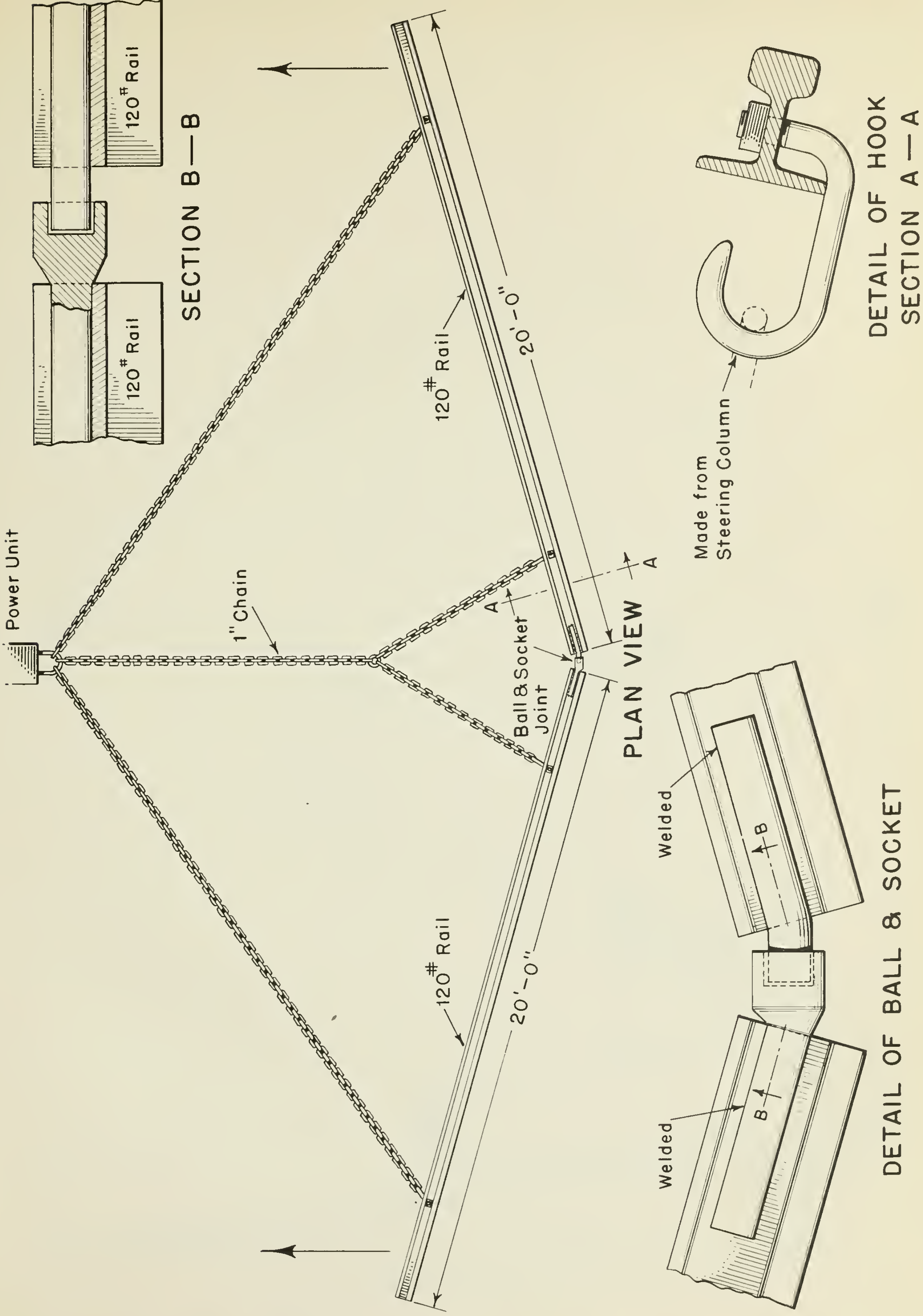

Fig. 4. Detailed sketch of Olson rail.

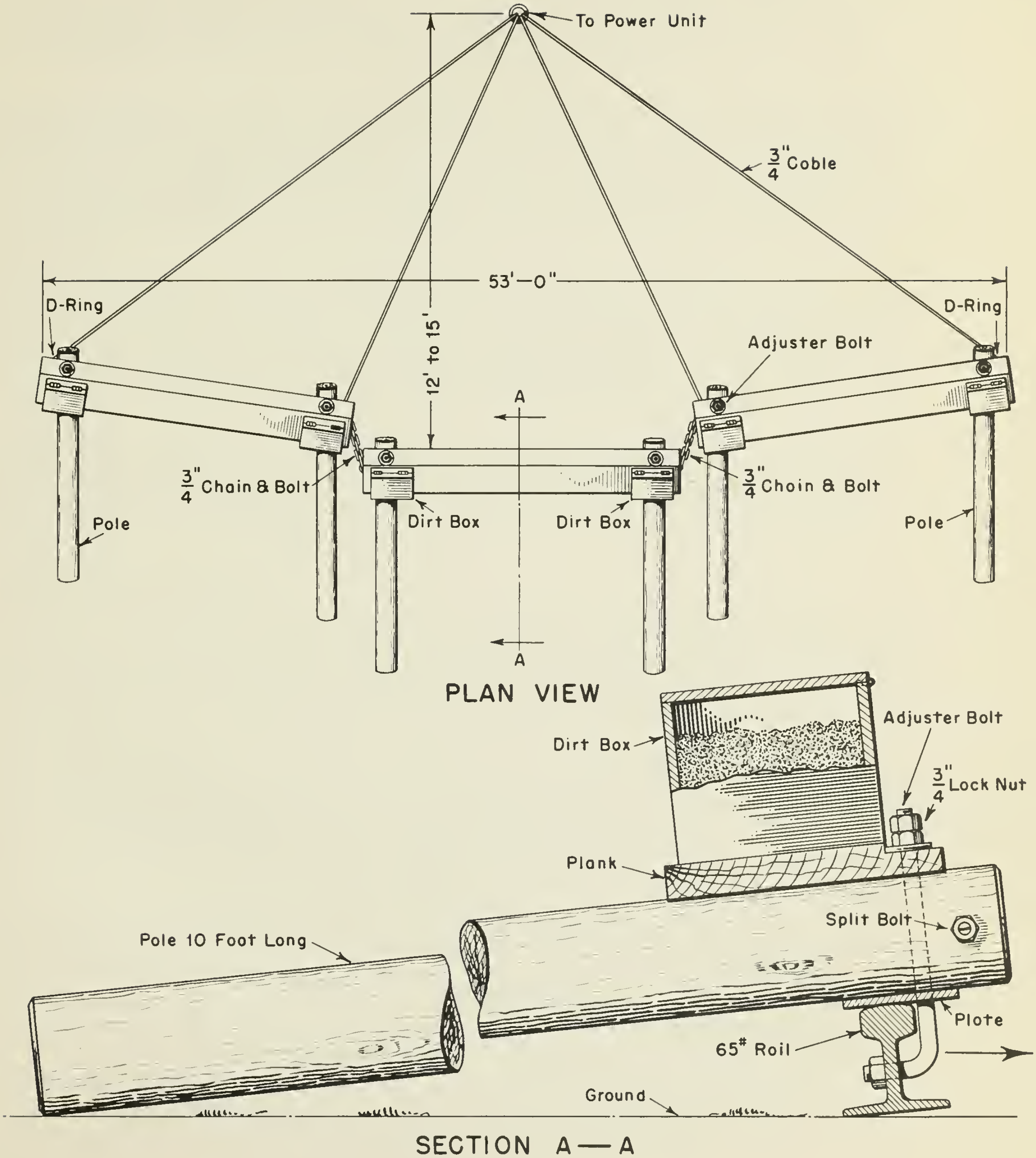

Fig. 5. Detailed sketch of Supp rail.

The Monte Cristo rail (fig. 6) has been used at rather low cost on large areas in northern Utah and has given fairly effective removal. The rail as shown in the sketch, is made up of one long section in front and two shorter ones behind. These shorter sections can drop into depressions which will be skipped by the long front section.

This rail is somewhat more costly to construct than other types because of the large amount of welding involved, and it is much more difficult to transport because of the long front section. On the other hand, it is sturdy and has given fairly good performance.

The A-frame rail (fig. 7) has been used primarily for removing sagebrush from sagebrush range land being broken for farming, but it has not been used in range improvement. It is made from heavy railroad rails assembled to form an "A". Two fins that dig into the soil and keep the rail going straight forward are mounted at the center of the cross members.

This rail gave a good sagebrush kill. People who have used it say it has low draft and a shearing action on the sagebrush. On the other hand, it is said breakage is frequent because sharp or moderately sharp turns will twist the fins and either break them off or break the cross members. The fins will also break or twist if they hit imbedded rocks.

Many *other rails* have been used for sagebrush eradication, but it is not known whether they have been tried on range improvement. Sketches are presented in figure 8 of three other rail designs that may have some desirable features.

Procedure in Railing

In open, even-aged mature stands of sagebrush satisfactory eradication may be obtained by pulling the rail over the sagebrush only once. But ordinarily, where the sagebrush is dense, or uneven-aged, it is necessary to rail in reverse directions to secure a satisfactory kill.

Most rails automatically dump themselves when loaded with brush but often some furrowing results from dragging wads of brush. Rails should not be pulled at a high rate of speed because they may jump over piles of brush or uneven ground and leave sagebrush untouched.

On stands of uneven-aged sagebrush, burning is often possible after railing where it wasn't before. With this method the range is railed once and fire set to the piles of brush. The fire tends to spread from the piles to the lower and younger sagebrush. Approximately 99 percent of all sagebrush, in a very uneven-aged stand where this was tried, was killed by railing once and burning. On the other hand railing-and-burning leaves but little litter on the ground, destroys some organic matter, and a fire line may be needed around the range area being railed and burned. Perennial grass beneath the piles of brush is destroyed by the fire and in the one case where this method was used nearly 75 percent of the Sandberg bluegrass was killed.

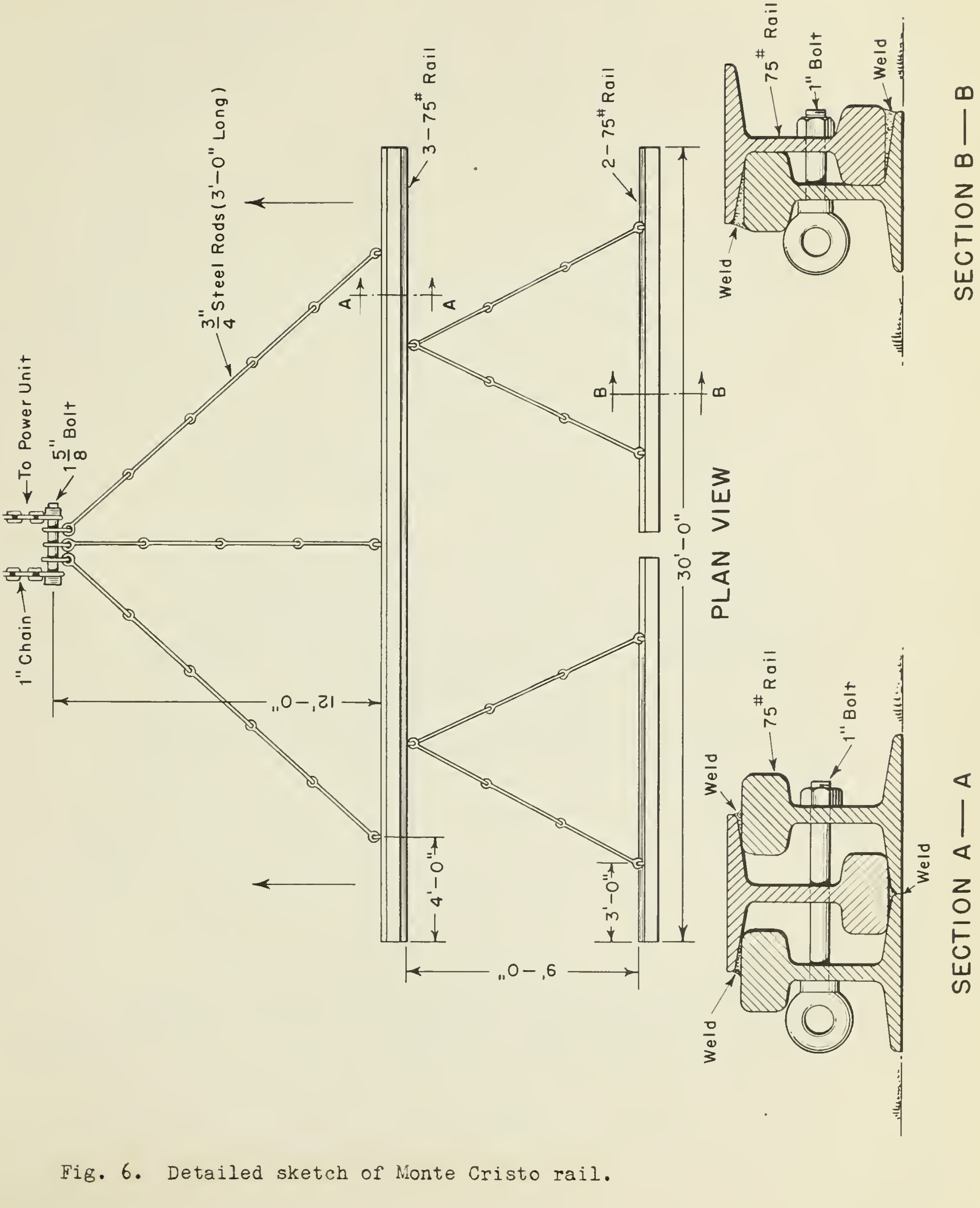

Fig. 6. Detailed sketch of Monte Cristo rail.

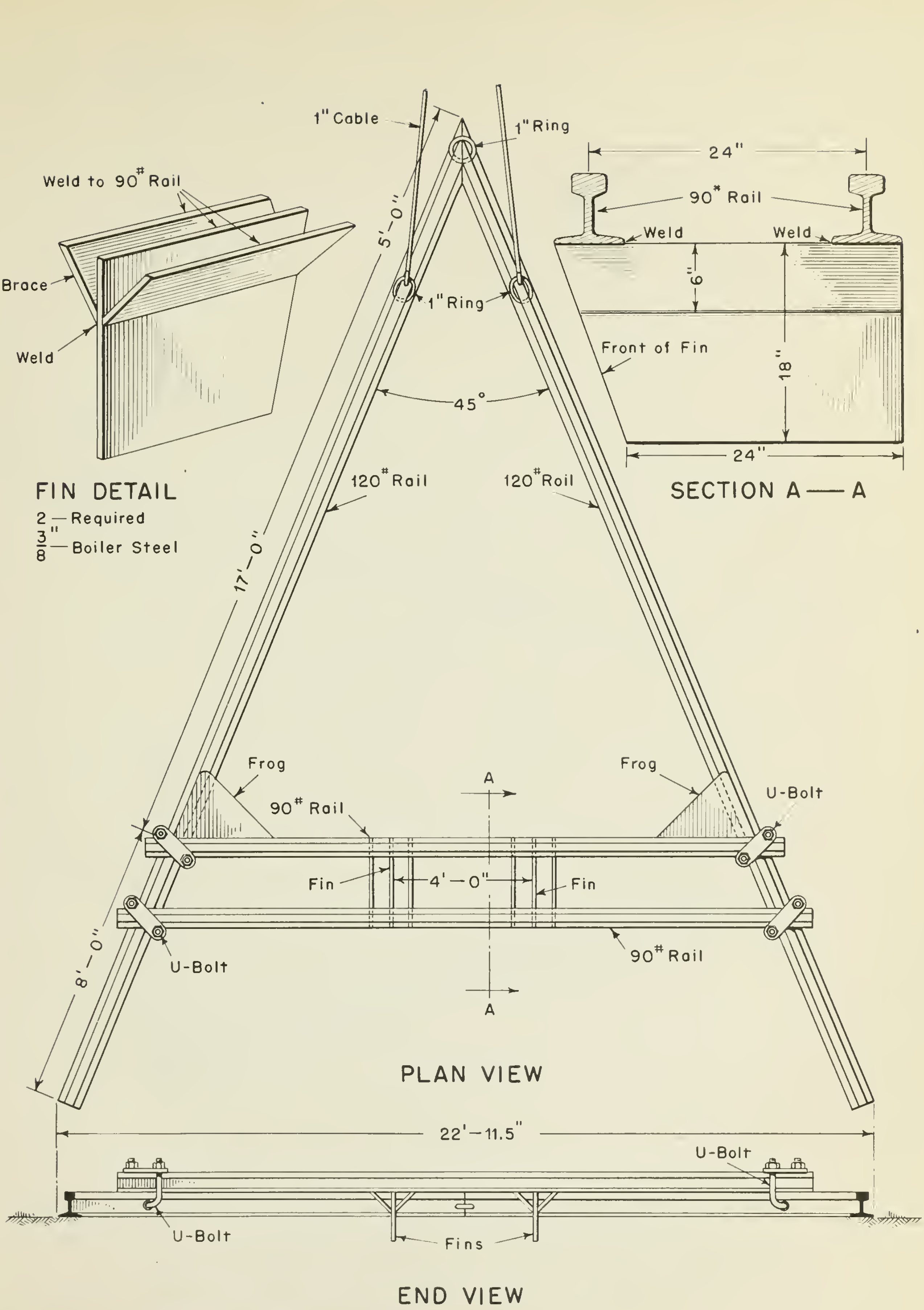

Fig. 7. Detailed sketch of A-frame rail.

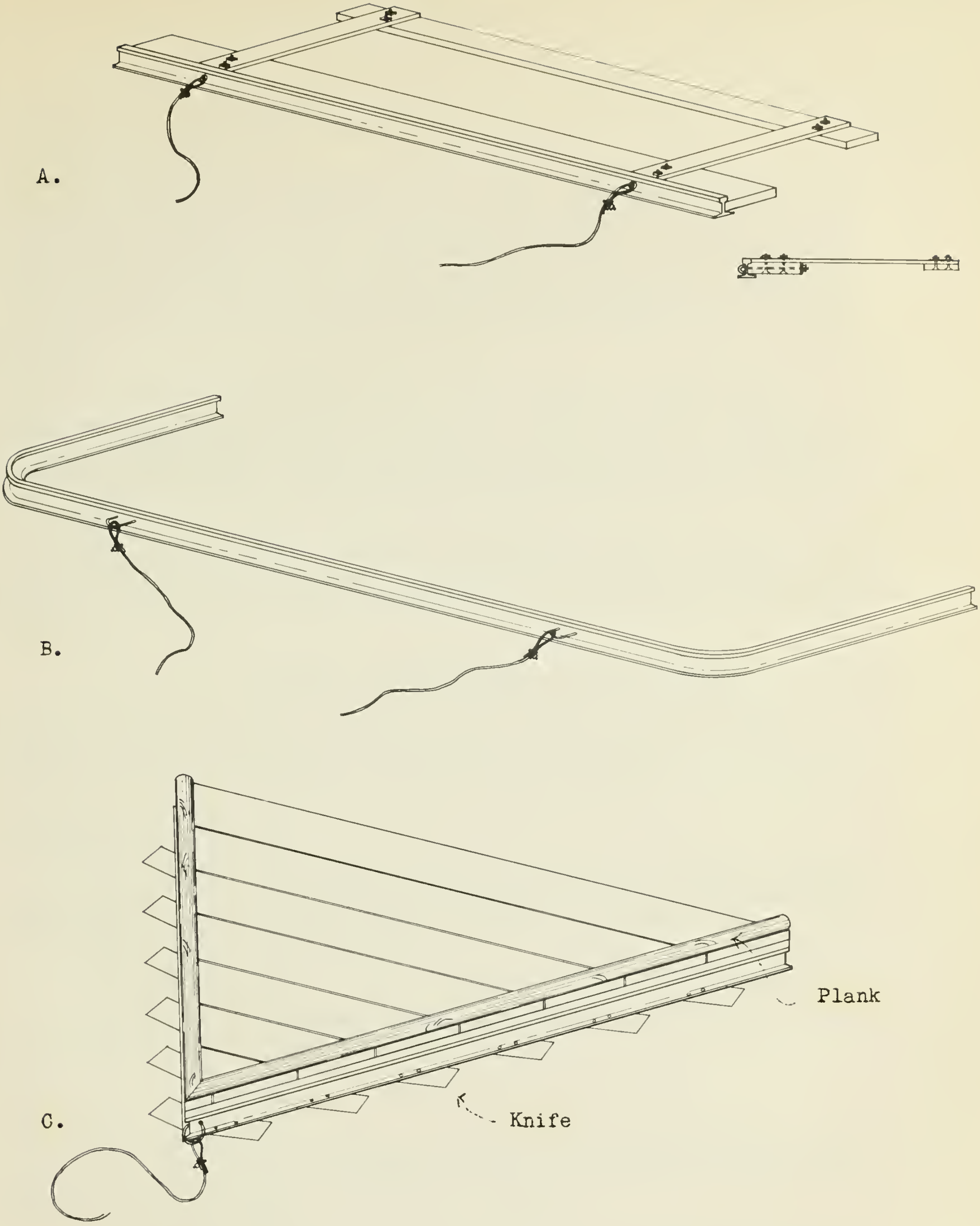

Fig. 8. A. View of a common type of rail used in clearing sagebrush, showing method of fastening platform and hitch to rail. B. Long length of railroad rail with 5 feet of rail bent back at either end. Rail 14 to 16 feet across at base of the "U". C. V-shaped rail made from railroad rail, with pieces of grader blade drawn to a sharp edge projecting in front and bolted to the base of the rail.

Rate per Hour and Costs

By railing once over the area the following acreages have been covered: approximately 9 acres per hour using a 53-hp. tractor and 37-foot rail on rolling terrain and fairly heavy sagebrush; nearly 12 acres per hour using a 45-hp. tractor with a 40-foot rail in much more open sagebrush and more level terrain; and 6 acres per hour using a 35-hp. tractor and a 26-foot rail in extremely dense, uneven-aged sagebrush. Railing an area twice in reverse directions, would cut the above acreages almost in half.

Costs of railing are generally low. Large tracts of range land exceeding 1,000 acres in size have been railed at costs of between $0.25 and $0.50 per acre for railing once, and from $0.45 to $0.90 per acre for railing twice. Two smaller tracts of from 100 to 200 acres were railed in two directions for $0.84 and $1.94 per acre.

Railing-and-burning costs from $0.60 to $0.90 per acre. One man, setting fires to piles of brush, can burn 15 to 20 acres per day. Under conditions that favor burning in late summer or early fall he can burn much more.

HARROWING FOR SAGEBRUSH ERADICATION

Self-clearing log or pipe harrows, or Dixie drags have been used primarily for covering seed on range lands. In some places they have also proved quite effective for eradicating sagebrush.

Advantages of Harrowing

1. Harrowing can be used to good advantage on land too rough and rocky to plow. It works much better than the wheatland plow where the area is badly cut up by small gullies, 2 to 3 feet deep.

2. Perennial bunchgrasses and weeds are damaged only slightly.

3. Grass seed is covered rather effectively in same operation as eradication.

Limitations of Harrowing

1. Kill is not very high where sagebrush is young, flexible, and tough, or low in stature or stands are open. Nearly 80 percent of old, brittle sagebrush in dense stands may be killed.

2. With present harrow designs, pipes of the harrow roll on top of one another when used on slopes steeper than 20 percent. An evener attached behind the pipes may overcome this handicap.

Even though tests have never been conducted under comparable conditions, it appears that the self-clearing harrow can be used on rough and rocky

ranges to better advantage and at less cost than the ripper, unless there is some reason for having the ground torn up more deeply.

Equipment Needed and Procedure

A self-clearing harrow and a tractor are needed for harrowing. The harrow can be constructed in widths that will utilize most efficiently the power of the tractor available.

A good harrow can be made using 8- to 10-foot lengths of 4-inch pipe or well casing. Approximately 8 to 10 mild steel teeth about an inch in diameter are put through each pipe, and welded in place so that they protrude about 6 inches on each side of the pipe. Teeth are arranged spirally so that they cause the pipe to rotate and clear itself. Old automobile or mowing machine axles make good teeth. Ends of the teeth should be drawn to a point and faced with hard steel before welding the teeth in the pipe.

Pipes spaced 16 inches apart are attached to an evener using a 6-inch length of 5/8-inch chain with a swivel. The swivel allows the pipe to rotate freely.

Green logs 6 to 10 inches in diameter (fig. 9) can be substituted for pipes but will last only a season. When logs are used old drill steels driven through the holes bored slightly smaller than the diameter of the teeth will hold tight until the log dries.

Harrowing once over the area is usually sufficient to cover the seed although going both ways may greatly increase the kill of sagebrush.

Rate per Hour and Costs

Harrowing and wheatland-plowing, when done under comparable conditions, should cover about the same number of acres per hour and reach about the same costs per acre. An average of 1.8 acres per hour was attained on 125 acres treated by the Manti National Forest, using a 28-hp. tractor and a self-clearing harrow 10 feet wide. At this rate of accomplishment harrowing would cost $1.20 per acre.

RIPPING SAGEBRUSH WITH A ROAD RIPPER

Using a road ripper to break off and tear up sagebrush has been tried in a limited way on high summer range lands.

Advantages of Ripping

1. Ripping is effective on range too rough and rocky to plow.

2. There is not much danger of equipment breakage.

3. Ripping loosens the surface of hard, tight soils and prepares a good seedbed for broadcasting.

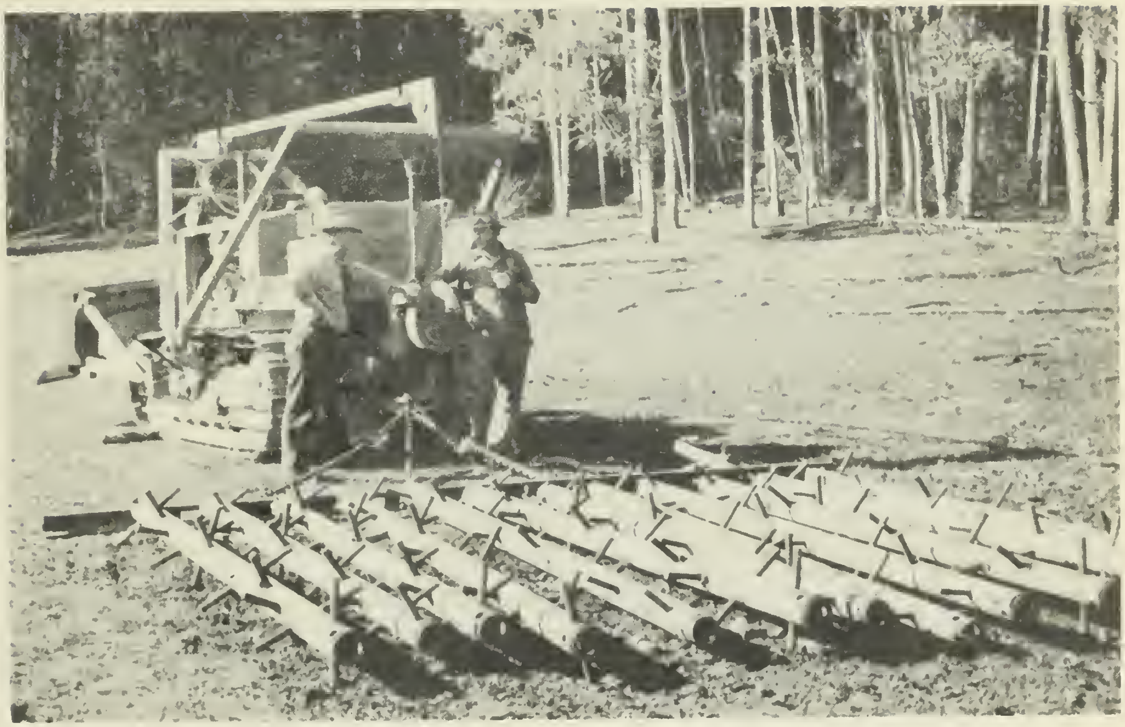

Fig. 9. Self-clearing pipe harrow that has been used in sagebrush eradication work.

Limitations of Ripping

1. Ripping is not very effective on young, flexible or short sagebrush. It tears out up to 80 percent of large old sagebrush but doesn't kill more than 30 percent of the small flexible sagebrush.

2. Up to 35 percent of the perennial bunchgrasses may be killed, if the ripper teeth are spaced only 14 to 16 to 18 inches apart.

3. Costs are high with present types of rippers, probably twice those of wheatland-plowing.

Equipment and Procedure

A 30- to 45-hp. crawler-type tractor, and a 2-ton road ripper are used for sagebruch eradication. A self-clearing ripper has the advantage of being easily cleared of brush while in motion (fig. 10). It is claimed that teeth should be set as closely together as possible, 14 to 16 inches apart on self-clearing models.

In eradication, setting the teeth to dig deeper than 4 to 6 inches increases the draft materially and may do so without increasing sagebrush kill. Larger sagebrush 3 to 4 feet high is broken down by the bars and frame of the ripper, and the ripper teeth root out the sagebrush directly in their path as well as tearing roots of all shrubs in the soil level to which the teeth penetrate. Insufficient information is at hand to show whether increased kill as result of root-pruning at greater depths will warrant the increased draft and greater costs of setting the teeth deeper.

Rate per Hour and Cost

Little is known of the cost of ripping or the acreage that can be treated per hour. From the width of a ripper, and the speed of travel, however, it is doubtful whether a 30- to 45-hp. tractor and a ripper measuring 6 feet between outside teeth can do much more than 3/5 to 1¼ acres per hour. On this basis the cost of ripping would be $1.90 to $3.15 per acre.

ROLLING SAGEBRUSH WITH SPIKED-ROLLER

A spiked-roller, similar to one developed by the Grazing Service in New Mexico for seeding creosote-bush types, was tried by the Owyhee District of the Grazing Service for mashing down sagebrush and seeding. On the basis of this very limited trial the following tentative conclusions have been drawn:

Advantages of Rolling

1. Rolling does not destroy perennial grass remnants.

2. Debris left on ground prevents wind and water erosion.

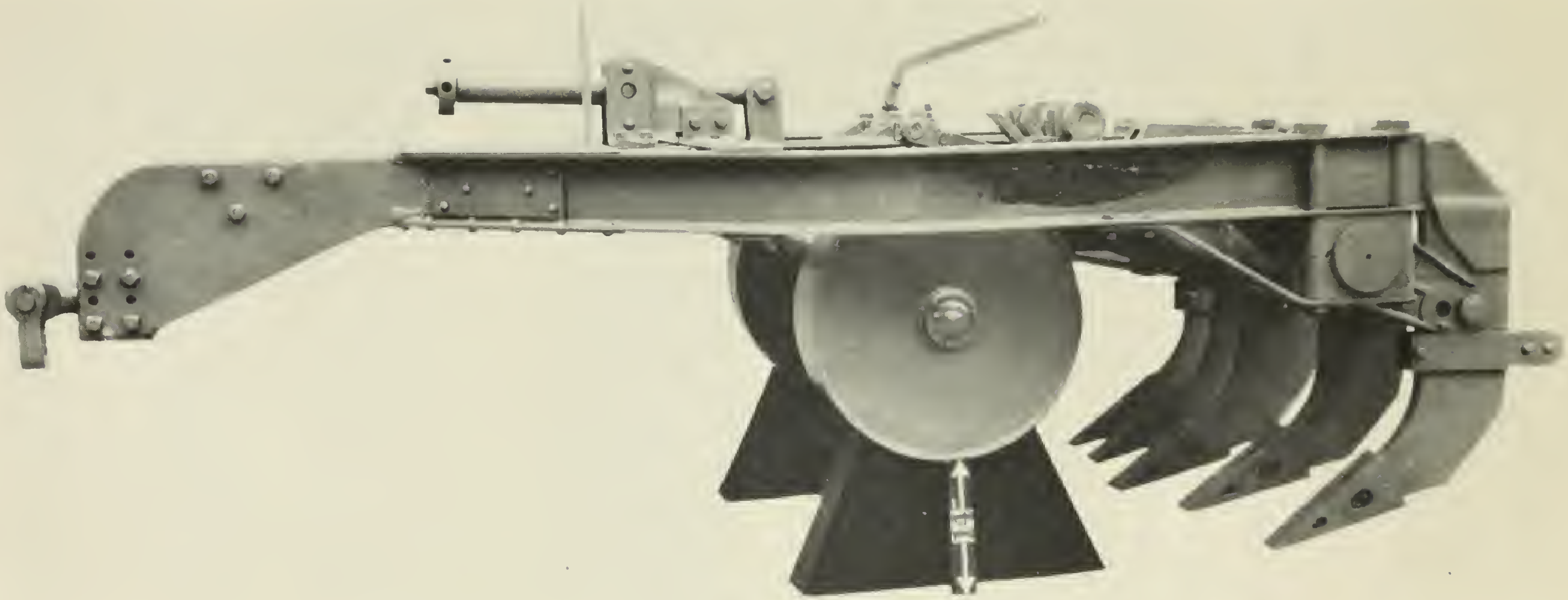

Fig. 10, Common type of self-clearing road ripper that has been found adaptable for sagebrush eradication.

3. Large, old sagebrush is rather effectively killed.

Other advantages found in New Mexico were that it was inexpensive--18 acres per day could be covered with 26-hp. tractor and an 8-foot roller; and the holes made by teeth permitted moisture to penetrate into the ground.

Limitations of Rolling

1. Costs are high with present types of equipment.

2. Rolling kills only a small percentage of younger sagebrush.

3. Rolling is unsatisfactory for covering seed. Less than 50 percent of the ground surface was disturbed. Corrugations on the roller pressed the seed down on the soil surface, but no coverage was given unless a tooth happened to hit the seed or throw dirt on it. On dry, hard ground even the corrugations did not touch.

4. It appears likely the teeth might be broken off or badly bent in very rocky soil.

Equipment Needed and Procedure

In the trial on sagebrush a 45-hp. crawler-type tractor was used to pull an 8-foot roller.

This roller (fig. 11) was made from an 8-foot length of 30-inch corrugated culvert fitted into the drawbar frame of an old rotary scraper. The culvert was centered on a piece of shafting which was cut to protrude 6 or 8 inches from either end. Teeth were made from old automobile axles cut to the proper length and the tips wedge-shaped. Holes were cut in the culvert through which the teeth protrude about 6 or 7 inches. Eight rows of teeth with 9 teeth per row were used. The culvert was then filled with concrete.

From the trial made it is suggested that, for use in sagebrush eradication and seeding, a smaller culvert 18 to 24 inches in diameter be used. A single tractor could then pull two or three units covering a far greater acreage and giving lower costs. At least twice the number of 3-inch teeth should give better soil disturbance and seed coverage or if grain drills attached behind the rollers were used for seeding it is possible that the teeth might be eliminated completely.

Nearly all the large, old sagebrush will be broken down by pulling the roller over an area once. It isn't known whether a second trip will provide additional kill of the younger sage.

Rate per Hour and Costs

Under fairly average conditions one operator with a 45- to 60-hp. tractor, and an 8-foot roller should be able to cover from 1.5 to 2

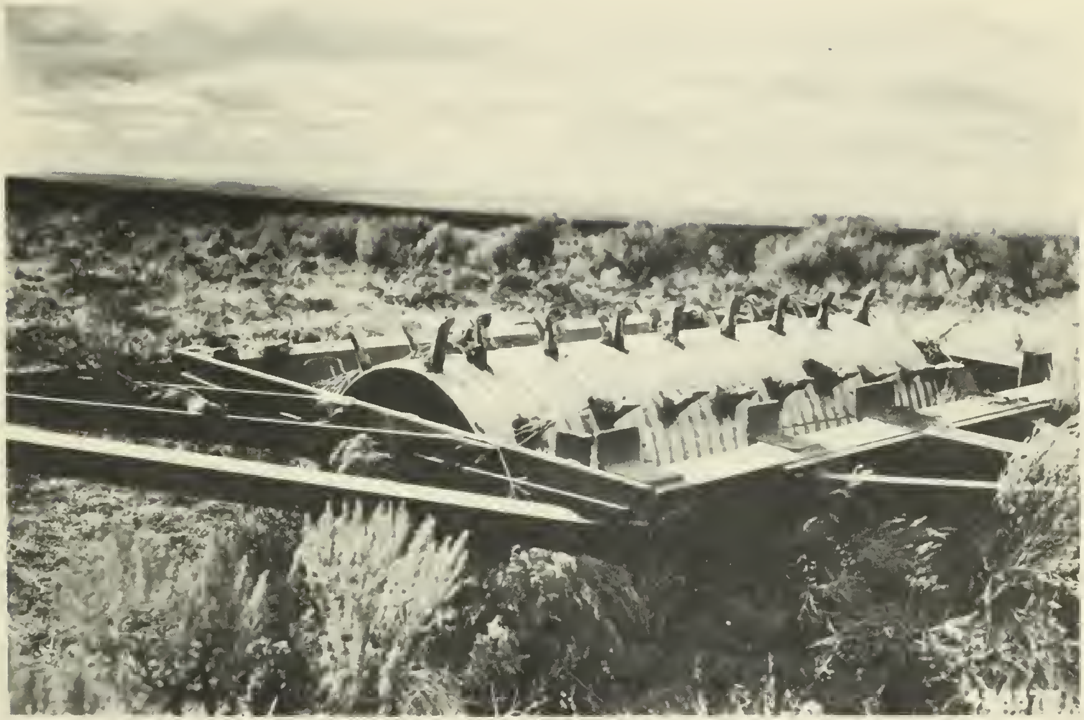

Fig. 11. Spiked roller being used for sagebrush eradication.

acres per hour at an average cost of from $1.50 to $2.00 per acre. With improvements in equipment design providing greater coverage and lower costs the roller might be developed into an efficient piece of equipment.

SCRAPING OFF SAGEBRUSH WITH A GRADER

This method has been used on only very limited tracts of range land, in a few cases for clearing farm land, and chiefly for constructing fire lines.

Advantages of Scraping

1. Almost 100 percent of all ages of sagebrush is killed.

2. Scraping is effective whenever weather and soil conditions permit its use.

Limitations of Scraping

1. The cost is likely to be high.

2. Destruction of perennial grasses and weeds, other than species spreading by rootstocks, is almost complete.

3. Scraping is not effective on extremely rocky soil or rough terrain.

Equipment Needed and Procedure

A crawler-type tractor with a 3- to 5-ton grader is needed for effective clearing. A heavy road patrol may also be used.

Usually once over an area with a grader or patrol will be sufficient for sagebrush eradication. The blade of the grader or patrol is set at such an angle that brush and some soil are thrown up in parallel windrows. Scraping should follow the contour where there is any shape.

Rates per Hour and Costs

No actual cost records are available for this method, but 2 men with a 45- to 55-hp. caterpillar-type tractor and a 3- to 4-ton grader should

be able to clear about $1\frac{1}{2}$ acres of sagebrush range per hour, at a cost of $2.50 to $3.00 per acre.

GRUBBING SAGEBRUSH WITH MECHANICAL GRUBBER

Mechanical sagebrush grubbers have been widely used and are claimed to be one of the most efficient pieces of equipment made for clearing sagebrush land for farming. Just recently one model of the grubber was used for range improvement in western Nevada by the Grazing Service.

Advantages of Grubbing

1. All shrubs are eradicated, regardless of species, size, or age. If desired after grubbing, the brush can be readily raked into piles and burned.

2. The soil surface well-stirred up to receive broadcast seed.

Limitations of Grubbing

1. Grubbing is fairly costly.

2. It cannot be used very well on rocky soil or rough terrain.

3. Bunchgrasses and perennial weeds are completely destroyed.

Equipment Needed and Procedure in Grubbing

Two types of grubbers are known to have been used. One is made up of a heavy forward roller for pressing down the brush and preventing sideslipping, and three large duckfoot shovels mounted on very heavy shanks which can be raised and lowered by overhead gears. The implement grubs a swath 7 feet wide. It requires a 40- to 45-hp. tractor to pull it.

Another grubber, widely used throughout southern Idaho and eastern Oregon, consists of a single large V-shaped knife, 5 to 9 feet across between the points at the rear. This blade is made of 3/4-inch steel and drawn to a sharp edge in front. Attachment of the blade is at three places--the point and just ahead of either tip of the "V". This assembly mounted on high wheels is called the "high grubber" and is used for tall sagebrush. When mounted on low wheels (fig. 12) it is used primarily for sagebrush of shorter stature. The assembly is equipped with a lever so that the blade can be raised or lowered. The blade when in operation is drawn along parallel to and 2 or 3 inches beneath the ground surface. Weight can be placed on the platform above if needed to keep the blade in the ground and the wheels on the ground. A 20- to 25-hp. tractor is required to pull a 5-foot model and a 40- to 45-hp. tractor is needed for a 9-foot model.

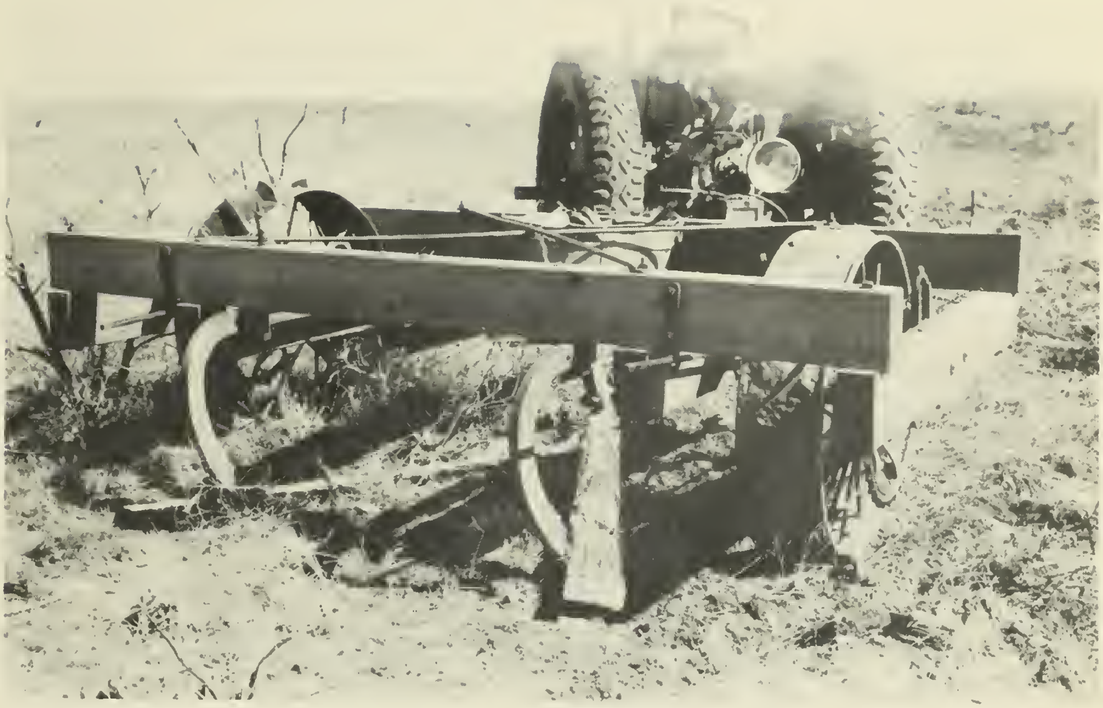

Fig. 12. Low-wheel sagebrush grubber commonly used for sagebrush eradication.

Rates per Hour and Costs

The only costs available are those from the 7-foot grubber used in western Nevada. When pulled by a 40- to 45-hp. tractor the grubber removed sagebrush on from 1½ to 1-3/4 acres per hour at a cost of $2.10 per acre.

MOWING SAGEBRUSH

Mowing has been used for eradication of sand sagebrush (*Artemisia filifolia*) in Oklahoma and northern Texas, and for eradication of silver sagebrush (*A. cana*) in Canada. Both these species have more slender stems than big sagebrush.

There is no known instance where mowing has been used for eradication of big sagebrush within the Intermountain region. Consequently, hardly enough is known about the operation to provide a basis for judging fully its advantages and limitations. There are, however, certain points that are clear.

Advantages of Mowing

1. There is no disturbance of perennial grasses and weeds.

2. Costs are moderately low. Savage[5] reports costs of about $1.50 per acre for eradicating sand sagebrush.

Limitations of Mowing

1. Mowing would not be feasible where there is much surface rock because of high equipment breakage, or slow rate of accomplishment.

2. Mowers or brush cutters using cutter bars and knives now available will not handle sagebrush with trunks greater than 3 inches in diameter. Much big sagebrush in old stands may run 5 inches or more in diameter. The brush cutter employing a circular saw would handle this larger brush, but is likely to be extremely dangerous where there is much loose rock.

Equipment Available and Procedure

The mower used in Oklahoma and northern Texas for mowing sand sagebrush is a power take-off mower having an ordinary 5-foot bar, equipped with snub-nosed brush guards, heavy-smooth sections, and a double set of slips to hold the sections snugly against the blunt guards.

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[5] Savage, D. A. Twice the Beef--for $1.50 per Acre. Country Gentleman. May, 1944, p. 22. Illus.

An experimental brush cutter developed by the Portland Machinery Laboratory of the Forest Service, consisting of an independently powered mower mounted on a truck chassis, or the Jaques Mobile Saw developed in Texas might also have some value for sagebrush eradication work.

Mowing was most effective when carried on between May 15 and June 15, once each year for two successive years. Mowing may have a place in the control of big sagebrush. With present types of equipment it should be effective on and practical for destroying stands of young sagebrush that have come in on reseeded areas or on rock-free native range. For use in mature sagebrush stands it may be worthwhile to develop equipment and procedures that will be effective.

FLOODING SAGEBRUSH FOR ERADICATION

One of the oldest but least widely applicable methods for killing big sagebrush is by flooding. Good kills of sagebrush have been obtained and excellent stands of grass restored. Where ample spring flood waters are available sagebrush may be killed by keeping the ground covered and saturated with water for several weeks during the spring. In order to do this water must be spread through efficient spreading systems.

Flooding may not always provide a good kill in big sagebrush; neither does it facilitate seeding afterward. It may be ineffective when porous soils or substrata allow water to drain away rapidly. It is ineffective on most other shrub species.